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(54) Title: MOTOR FUEL FOR DIESEL ENGINES

(57) Abstract: The invention relates to a motor fuel for diesel engines comprising hydrocarbon compounds and/or organic compounds containing bound oxygen, which constitutes a stable homogeneous liquid at atmospheric pressure and normal ambient temperature and achieves a reduction of harmful pollulants in the exhaust emissions of diesel engines by adding at least four different types of organic compounds containing oxygen bound in certain functional groups to the fuel composition. In the resulting fuel composition the total concentration of organic compounds containing bound oxygen in the fuel composition varies within the limits of minimum 5 % and of maximum 100 % of the total volume of the fuel composition, and the concentration of the hydrocarbon compounds varies, correspondingly, within limits of maximum 95 % and of minimum 0 % of the total volume of the fuel compositon.

MOTOR FUEL FOR DIESEL ENGINES

Field of the invention

The invention relates to motor fuel for diesel engines consisting of fuel compositions of hydrocarbon compounds and organic compounds containing bound oxygen. Additionally, this invention relates to motor fuel for diesel engines in which the fuel composition constitutes a stable, homogeneous liquid at atmospheric pressure and normal ambient temperature.

Background to the invention

The problem of the reduction of pollutants in the exhaust emissions of diesel driven engines is a challenge to modern society. It is proposed to replace diesel as a fuel for vehicles because of environmental reasons and also due to its effects on health. There are international agreements providing for the progressive tightening of the requirements concerning the amount of toxic products resulting from the combustion of motor fuel in the exhaust emissions of vehicles and other machines using diesel engines. In the European Union countries and in the USA the requirements of Step II come into force starting from year 2002. The requirements stipulate significant decreases of carbon monoxide (CO), mixtures of hydrocarbons and nitrogen oxides ($HC+NO_x$), and particles in the exhaust emissions of diesel engines.

Moreover, modern society is preoccupied with the damage to the global balance of carbon dioxide in the atmosphere, which is linked to the intensive burning of petroleum products, coal and fossil gas. The damage to the carbon dioxide balance in the atmosphere causes global climate warming and has a negative influence on the nature of our planet.

In this topical connection the development of motor fuel for engines obtained from renewable plant resources is of real significance.

The growing concern for the protection of the environment and for stricter standards in the content of harmful components in exhaust emissions forces industry to develop urgently various alternative fuels which burn more cleanly.

The existing global inventory of vehicles and machinery with diesel engines does not allow currently the complete elimination of diesel oil as a motor fuel.

On the other hand it is possible to replace part of the diesel oil in motor fuel by other organic compounds which provide cleaner emission exhaust and do not affect engine performance. It is known, for instance, that the replacement in motor fuel of 15% of the diesel by alcohol provides cleaner exhaust and provides acceptable power without modification of the existing diesel engines.

However, the problem of using the most widely available and inexpensive alcohols, methanol and ethanol, as a part of a motor fuel is that these compounds are immiscible with diesel. Potentially, alcohols and other oxygen containing compounds should have environmentally clean products of combustion. However, the combustion process in engines is an extremely complicated phenomenon, which is affected not only by the composition of the fuel but also by the fuel's physical parameters, and in the first instance by the homogeneity of the liquid.

We performed a novelty search through scientific, technical and patent information on the subject, "Homogeneous liquids consisting of a diesel fraction of petroleum processing products and of organic compounds containing bound oxygen, including alcohols, which may be used as a motor fuel for diesel engines". The search was done for a period of thirty years back. As a result of the search the relevant sources of information were identified, and we consider those in this overview.

The feasibility and properties of mixtures of petroleum diesel fraction with ethanol was reported a long time ago (Technical Feasibility of Diesohol, ASAE Paper 79-1052, 1979). It was stressed in the article that the main problem of the use of such a fuel is its tendency to phase separation, furthermore, the phase separation is significantly affected by the presence of water in the system. At 0°C a water content of 0.05% causes separation of motor fuel consisting of 99% diesel and 0.95% ethanol.

It is confirmed that alcohol containing fuels provide relatively low emissions of carbon, carbon oxide and nitrogen oxide (Johnson R.T., Stoffer J.O., Soc. Automot. Eng. (Spec. Publ.) 1983, S.P. 542, 91-104).

A significant part of the developments in the field of hybrid diesel fuels is dedicated to the creation of microemulsions. Microemulsions are thermally stable colloid dispersions in which the particle diameter is several tens of angstroms. In 1977 Backer proposed surfactants for microemulsions of alcohols and hydrocarbons (Great Britain patent 2002400, cl. C08G63/76, granted 12.07.1977).

Later, for the same purposes other emulgators were proposed (Great Britain patent 2115002, cl. C10L 1/18, granted 01.02.1982; U.S. patent 4509950, cl. 44/51 granted 24.03.1983, U.S. patent 4451265, cl. 44/51, granted 21.04.1984; European patent 475620, cl. C10L 1/32, priority 07.09.1990). It is possible to achieve homogeneous composition of diesel fuel incorporating different alcohols and their mixtures. In the French patent 79-08750, cl. C10L 1/18, priority 06.4.1979, in order to achieve a homogeneous liquid incorporating hydrocarbons and methanol it is proposed to add also primary aliphatic saturated alcohols of linear and branched structure having from 8 to 15 carbon atoms or mixtures of such alcohols. The avoidance of the separation of the hybrid fuel incorporating the alcohol mixture allows the development protected by the European patent 319060, cl. C10L 1/02, filing date 08.11.1988.

The study of the performance characteristics of the hybrid fuels confirms the possibility of their use for the operation of diesel engines (Mathur H.B., Babu M.K. Indian Inst. Techn. Journ. Therm. Eng., 1988, 2(3), p. 63-72. Haschimoto, K., et al., Journ. Jap. Petrol. Inst., 1996, v. 39, N2, p. 166-169).

The closest development related to our invention appears in patent W095/02654 PCT/AU 94/00401, priority date 16 July 1993, international date of publication 26 January 1995.

To achieve a homogeneous fuel blend the authors of the patent propose using a formulation containing up to 20% of the total volume of ethanol and/or n-propanol, up to 15% of the total volume of fatty acid and/or organic ester, and the remainder a

hydrocarbon liquid. The patent provides examples of compositions in which oleic acid as well as different organic esters are used in addition to diesel, ethanol and propanol.

In accordance with the patent all the example compositions occur in a single phase. This demonstrates the effectiveness of using certain amounts of fatty acids and/or organic esters, as well as their mixtures, in order to obtain homogeneous liquids incorporating diesel and low alkyl alcohols in addition to those mentioned above. It is stated in the patent that tests of several compositions on various standard diesel engines did not show a decrease of power and efficiency of the fuel.

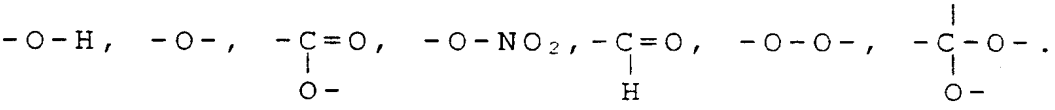
However, nothing is said in the patent about the content of the exhaust emissions of different engines using the fuel formulations proposed by authors.

The only comment in this regard is that the use of the ethanol blend over several months in the engine of a Yale Forklift (model GDP 050 RUAS) Mazda XA was likely to be more acceptable with regard to the air condition inside the warehouse where the forklift was operated.

Summary of the invention

The invention is based on the selection of specific organic compounds containing bound oxygen added in certain proportions with hydrocarbons, or without these, at atmospheric pressure and normal ambient temperature. A homogeneous liquid is formed which, when used as a motor fuel, provides the required operational characteristics of diesel engines and a lower quantity of pollutants in the exhaust emissions.

In a first embodiment of the invention of the motor fuel mentioned above the organic compounds containing bound oxygen which are suitable are any compounds containing oxygen bound in the following functional groups:



According to a preferred embodiment of the invention for a fuel composition resulting in a homogeneous liquid giving cleaner combustion in diesel engines, we provide the classes of the organic compounds containing bound oxygen in the functional groups

defined above as: alcohols, aldehydes, ethers, organic esters, inorganic esters, acetals, organic acids and peroxides.

According to a preferred embodiment of the invention for a homogeneous fuel composition providing an efficient operation of diesel engines and the reduction of pollutants in the exhaust emissions we provide the necessary conditions as the following:

- the use of at least four types of organic compounds differing in functional groups containing bound oxygen, selected from the following classes: alcohols, aldehydes, ethers, organic esters, inorganic esters, acetals, organic oxides and peroxides.
- detection of the proportion of components composing the fuel composition within limits for total concentration of the organic compounds containing bound oxygen as a minimum 5 % and as a maximum 100 % by volume of the total amount, and for a concentration of hydrocarbons, respectively, as a maximum 95 % and as a minimum 0 % by volume of the total amount;
- provision of physical and chemical properties on the following levels:
  - for density, not less than 0.775 g/cm^3 at 20°C;
  - for cloud temperature, not higher than 0 °C at atmospheric pressure;
  - for temperature limits of evaporation by boiling at atmospheric pressure:

    the initial boiling point not lower than from 50 °C

- up to 100 °C	not more than 25 % of the total volume of the liquid;
- up to 150 °C	not more than 35 % of the total volume of the liquid;
- up to 200 °C	not more than 50 % of the total volume of the liquid;
- up to 370 °C	not less than 98% of the

total volume of the liquid;

- for heat of combustion of oxygen in the atmosphere, not less than 39 MJ/kg;
- for self-ignition temperature not less than 150 °C and not higher than 300 °C;
- a procedure for the preparation of the motor fuel by means of pouring together of the required amount of components in the same tank at the same temperature in a pre-determined order as follows, starting with the component having at that temperature the least density and finishing with the component having the highest density, and holding the mixture obtained for not less than one hour.

According to a preferred embodiment of the invention for a fuel composition giving a shorter period of delay in the ignition of the motor fuel the organic compounds containing bound oxygen preferably have a linear or sparsely branched molecular structure.

According to another preferred embodiment of the invention for a fuel composition containing organic compounds containing bound oxygen with a branched molecular structure in which the efficiency of operation is not reduced we provide the temperature of self-ignition of the final fuel composition as being between 150 °C and 300 °C.

According to another preferred embodiment of the invention for a fuel composition providing for the efficient operation of diesel engines and reduction of pollutants in the exhaust emissions without the addition of hydrocarbons to the fuel composition, using for this purpose only organic compounds containing bound oxygen.

According to another preferred embodiment of the invention, the motor fuel also includes organic compounds containing bound oxygen which are not thoroughly purified technical products.

According to another preferred embodiment of the invention, the motor fuel also includes methanol and/or ethanol as well as products arising from their processing as the organic compounds containing bound oxygen.

According to another preferred embodiment of the invention, there is the application of the motor fuel under conditions of reduced or increased ambient temperature.

According to another preferred embodiment of the invention, there is the application of the motor fuel under conditions of the presence of water in the fuel composition of up to 1% of total volume.

According to another preferred embodiment of the invention, the organic compounds containing bound oxygen also include organic compounds obtained from renewable plant resources.

Examples

As non-limiting examples demonstrating the efficiency of this invention the fuel compositions described below prepared according to the invention are suitable for the operation of diesel engines, including standard types.

Composition 1 demonstrates the minimum quantity of organic compounds containing bound oxygen added to a hydrocarbon liquid which provides a noticeable reduction of pollutants in the exhaust emission of a diesel engine operating with this fuel composition.

The content by volume of components in the fuel composition: formaldehyde diethyl acetal 1 %, 1-butanol 1 %, di-n-amyl ether 1.75 %, octyl acetate 1 %, isopropyl nitrate 0.25 %, hydrocarbon liquid (diesel fuel SS 15 54 35 Mk1) 95 %.

The fuel composition has the following characteristics:

- density at 20°C 0.811 g/cm^3
- temperature limits of evaporation by boiling of

the liquid at atmospheric pressure

up to 100°C	1 %
up to 150°C	2.25 %
up to 200°C	14.5 %
up to 285°C	95.25 %

- heat of combustion 42.8 MJ/kg
- thermal stability:

fuel composition 1 is a homogeneous liquid stable at atmospheric pressure over the range of temperatures from minus 18 °C (cloud temperature) to plus 88 °C (initial boiling temperature).

An analysis of the amount of pollutants in the exhaust emissions from the standard diesel engine of the VW GOLF CL DIESEL automobile, engine family: D1-W03-92 when executing Test Type, – Modified European Driving Cycle (NEDC UDC + EUDC) ECE OICA (91/441/EEC) on fuel composition 1 showed a reduction in particles (g/km) of 5 % in comparison to the results obtained for 100% Mk1 diesel fuel (SS 15 54 35).

The use of fuel composition 1 in the operation of the standard diesel truck engine, engine type VOLVO TD61GS No. 0580026, with power and torque settings: kW/Nm/rpm=140/520/1900, showed for measurements over the range of 1000 - 2600 rpm a decrease in the values of power and torque of less than 1 % in comparison with the figures obtained for the same engine operating on 100% Mk1 diesel fuel (SS 15 54 35).

Composition 2 demonstrates the possibility of obtaining a significant decrease of pollutants in the exhaust emissions of a diesel engine operating with an inexpensive fuel composition of organic compounds containing bound oxygen and a hydrocarbon liquid.

The content by volume of the components in the fuel composition: ethanol 3 %, 1-butanol 2.5 %, dimethoxypropane 3 %, ethyl acetate 1.5 %, tert-butyl hydroperoxide 0.5 %, hydrocarbon liquid (Mk1 diesel fuel SS 15 54 35) 89.5 %.

The fuel composition has the following characteristics:

- density at 20°C 0.817 g/cm^3
- temperature limits of evaporation by boiling of the liquid at atmospheric pressure
  - up to 100°C 7 %
  - up to 150°C 10.5 %
  - up to 200°C 19.5 %
  - up to 285°C 95.5 %
- heat of combustion 41.7 MJ/kg
- thermal stability:

  fuel composition 2 is a homogeneous liquid stable at atmospheric pressure over the range of temperatures from minus 30 °C (cloud temperature) to plus 70 °C (initial boiling temperature).

An analysis of the amount of pollutants in the exhaust emissions from the standard diesel engine of the VW Passat TDI 1.9 automobile, model 1997, Engine Family 2D1-WDE-95, power kW/rpm=81/4150 according to the Test Type – Modified European Driving Cycle (NEDC UDC + EUDC) ECE OICA (91/441/EEC) for fuel composition 2, showed in comparison to 100% Mk1 diesel fuel (SS 15 54 35) a reduction in the amounts of: CO (g/km) 12 %, HC+NO_x (g/km) 5.75 % and particles (g/km) 11.5 %.

An analysis of the amount of the pollutants in the exhaust emissions from the standard diesel truck engine, Engine Type: VOLVO D7C 290 EUR02 No. 1162 XX, power kW/rpm=213/2200 according to the Test Type: ECE R49 A30 Regulation for fuel

composition 2, showed in comparison to 100% Mk1 diesel fuel (SS 15 54 35) a reduction in the amounts of: CO (g/kW) 6 %, HC+NO_x (g/kW) 0 %, particles (g/kW) 4 %.

The power (PkW) of the engine when operating on fuel composition 2 decreased by 2.8%, and fuel consumption (l/kW) increased by 2 % in comparison to the results obtained for the same engine operating on 100% Mk1 diesel fuel (SS 15 54 35).

Composition 3 demonstrates the possibility of using for the operation of a diesel engine a fuel composition made of organic compounds containing bound oxygen and a hydrocarbon liquid containing lighter fractions of petroleum products in addition to diesel fuel.

The contents by volume of the components in the fuel composition are ethanol 8 %, 1-butanol 2 %, diethyl acetaldehyde 0.5 %, ethyl acetate 4 %, ethyl butyrate 3 %, acetaldehyde diethyl acetal 0.5 %, di-n-amyl ether 8 %, ethyl oleate 8 %, tert-butyl peroxyacetate 1 %, hydrocarbon liquid 65 %, in which part kerosene 15 % and Mk1 diesel fuel (SS 15 54 35) 50 %.

The fuel composition has the following characteristics:

- density at 20°C 0.775 g/cm^3
- temperature limits of evaporation of the liquid by boiling at atmospheric pressure
  - up to 100°C 12 %
  - up to 150°C 19 %
  - up to 200°C 43 %
  - up to 285°C 96 %
- heat of combustion 40.2 MJ/kg
- thermal stability:

fuel composition 3 is a homogeneous liquid stable at atmospheric pressure over the range of temperatures from minus 37 °C (cloud temperature) to plus 70 °C (initial boiling temperature).

An analysis of the amount of pollutants in the exhaust emissions from the standard diesel engine of the VW Passat TDI 1.9 automobile, model 1997, Engine Family 2D1-WDE-95, power kW/rpm=81/4150 according to the Test Type – Modified European Driving Cycle (NEDC UDC + EUDC) ECE OICA (91/441/EEC) for fuel composition 3, showed in comparison to 100% Mk1 diesel fuel (SS 15 54 35) a reduction in the amounts of: CO (g/km) 27.7 %, HC+NO_x (g/km) 12.6 % and particles (g/km) 17 %.

The use of composition 3 for the operation of the standard diesel truck engine, engine type VOLVO TD61GS No. 0580026, with power and torque settings: kW/Nm/rpm=140/520/1900, showed for measurements over the range from 1000 - 2600 rpm a decrease in the values of power and torque of less than 3.5 % in comparison to the figures obtained for the same engine operating on the 100% Mk1 diesel fuel (SS 15 54 35).

Composition 4 demonstrates the possibility of using for the operation of a diesel engine a fuel composition made of organic compounds containing bound oxygen and a hydrocarbon liquid in which the concentration of the latter in the composition can be less than 40 % by volume.

The contents by volume of the components in the fuel composition are ethanol 4.5 %, propanol 5.5 %, hexanol 15 %, dibutyl ether 8.5 %, ethyl caprylate 10 %, dihexyl ether 16 %, di-tert-butyl peroxide 1.5 %, hydrocarbon liquid (diesel fuel EN 590 : 1993) 39%.

The fuel composition has the following characteristics:

- density at 20°C 0.819 g/cm^3
- temperature limits of evaporation by boiling of

the liquid at atmospheric pressure

up to 100°C	10 %
up to 150°C	20 %
up to 200°C	39 %
up to 370°C	98 %

- heat of combustion 40.4 MJ/kg

- thermal stability:

fuel composition 4 is a homogeneous liquid stable at atmospheric pressure over the range of temperatures from minus 35 °C (cloud temperature) to plus 78 °C (initial boiling temperature).

An analysis of the amount of pollutants in the exhaust emission from the standard diesel engine of the Audi A6 TDI 1.9 automobile, model 1998 according to the Test Type – Modified European Driving Cycle (NEDC UDC + EUDC) ECE OICA (91/441/EEC), showed for fuel composition 4 in comparison to 100% Mk1 diesel fuel (EN 590 : 1993) a reduction in the amounts of: CO (g/km) 0 %, HC+NO_x (g/km) 14 % and particles (g/km) 46 %.

Composition 5 demonstrates the possibility of using for the operation of a diesel engine a fuel composition made from a hydrocarbon liquid and organic compounds containing bound oxygen which can be obtained by processing methanol and ethanol.

The contents by volume of the components in the fuel composition are methanol 1.5 %, ethanol 3 %, formaldehyde dimethyl acetal 2 %, formaldehyde diethyl acetal 3 %, acetaldehyde diethyl acetal 3 %, methyl acetate 1 %, ethyl formate 1 %, rape seed

methyl ether 5 %, ethyl oleate 5 %, tert-butyl peroxyacetate 0.5 %, hydrocarbon liquid (Mk1 diesel fuel SS 15 54 35) 75 %.

The fuel composition has the following characteristics:

- density at 20°C 0.821 g/cm^3
- temperature limits of evaporation of the liquid by boiling at atmospheric pressure
  - up to 100°C 11.5 %
  - up to 150°C 15 %
  - up to 200°C 25 %
  - up to 285°C 95.75 %
- heat of combustion 40.4 MJ/kg
- thermal stability: fuel composition 5 is a homogeneous liquid stable at atmospheric pressure over the range of temperatures from minus 33 °C (cloud temperature) to plus 52.5 °C (initial boiling temperature).

An analysis of the amount of pollutants in the exhaust emissions from the standard diesel engine of the VW Passat TDI 1.9 automobile, model 1997, engine family 2D1-WDE-95, power kW/rpm=81/4150 according to the Test Type – Modified European Driving Cycle (NEDC UDC + EUDC) ECE OICA (91/441/EEC), showed for fuel composition 5 in comparison to 100% Mk1 diesel fuel (SS 15 54 35) a reduction in the amounts of: CO (g/km) 0 %, HC+NO_x (g/km) 12.2 % and particles (g/km) 11.4 %.

The use of fuel composition 5 for the operation of the standard diesel truck engine, engine type VOLVO TD61GS No. 0580026, with power and torque settings: kW/Nm/rpm=140/520/1900, showed for measurements over the range from 1000 - 2600 rpm a decrease in the values of power and torque of less than 3 % in comparison with

the results obtained for the same engine working on 100% Mk1 diesel fuel (SS 15 54 35).

Composition 6 demonstrates the possibility of using for the operation of a diesel engine a fuel composition made of a hydrocarbon liquid and organic compounds containing bound oxygen which are not thoroughly purified technical products.

The contents by volume of the components in the fuel composition are ethanol 4.5 %, propanol 12.5 %, 1-butanol 1 %, isobutanol 0.5 %, 1-pentanol 1.5 %, 2-ethylhexanol 9.5%, ethyl acetate 1 %, propyl acetate 6 %, isobutyl acetate 0.1 %, amyl acetate 0.4 %, butyl aldehyde 0.8 %, isobutyl aldehyde 0.2 %, dibutyl ether 6.5 %, di-octyl ether 5 %, n-amyl nitrate 0.5 %, hydrocarbon liquid (diesel fuel SS 15 54 35 Mk1) 50 %.

The fuel composition has the following characteristics:

- density at 20°C 0.815 g/cm^3
- temperature limits of evaporation of
  the liquid by boiling at atmospheric pressure
  - up to 100°C 25 %
  - up to 150°C 35 %
  - up to 200°C 50 %
  - up to 285°C 97.5 %
- heat of combustion 39.0 MJ/kg
- self-ignition temperature 300 °C
- thermal stability:
  fuel composition 6 is a homogeneous liquid stable at atmospheric pressure over the range of temperatures from minus 35 °C (cloud

temperature) to plus 64 °C (initial boiling temperature).

An analysis of the amount of pollutants in the exhaust emissions from the standard diesel engine of the VW GOLF CL DIESEL automobile, Engine Family: D1-W03-92 when executing Test Type – Modified European Driving Cycle (NEDC UDC + EUDC) ECE OICA (91/441/EEC) showed for fuel composition 6 in comparison to the results obtained for 100% Mk1 diesel fuel (SS 15 54 35) a reduction in the amounts of: CO (g/km) 16.9 %, $HC+NO_x$ (g/km) 5.9 % and particles (g/km) 23.7 %.

The use of fuel composition 6 for the operation of the standard diesel truck engine, engine type VOLVO TD61GS No. 0580026, with power and torque settings: kW/Nm/rpm=140/520/1900, showed for measurements over the range 1000 - 2600 rpm a decrease in the values of power and torque of less than 5 % in comparison to the figures obtained for the same engine operating with 100% Mk1 diesel fuel (SS 15 54 35).

Composition 7 demonstrates the possibility of using for the operation of a diesel engine a fuel composition consisting of a hydrocarbon liquid and organic compounds containing bound oxygen which is expedient for use under elevated ambient temperatures.

The contents by volume of the components in the fuel composition are 1-octanol 2 %, ethyl oleate 4 %, ethyl caprylate 2.5 %, di-n-amyl ether 4 %, di-octyl ether 15 %, acetaldehyde dibutyl acetal 2 %, cyclohexyl nitrate 0.5 %, hydrocarbon liquid (Mk1 diesel fuel SS 15 54 35) 70 %.

The fuel composition has the following characteristics:

- density at 20°C 0.816 g/cm^3
- temperature limits of evaporation of

the liquid by boiling at atmospheric pressure

	up to 100°C	0 %
	up to 150°C	0 %
	up to 200°C	19.5 %
	up to 285°C	96.5 %
- heat of combustion		42.5 MJ/kg
- thermal stability:		
	fuel composition 7 is a homogeneous liquid stable at atmospheric pressure over the range of temperatures from minus 36 °C (cloud temperature) to plus 184 °C (initial boiling temperature).	

An analysis of the amount of pollutants in the exhaust emissions from the standard diesel engine of the VW GOLF CL DIESEL automobile, engine family: D1-W03-92 according to Test Type – Modified European Driving Cycle (NEDC UDC + EUDC) ECE OICA (91/441/EEC), showed for fuel composition 7 a reduction in comparison to the results obtained for 100% Mk1 diesel fuel (SS 15 54 35) of: CO (g/km) 6.9 %, $HC+NO_x$ (g/km) 7.4 % and particles (g/km) 13.5 %.

An analysis of the amount of pollutants in the exhaust emissions from the standard diesel engine of the truck, engine type: VOLVO D7C 290 EUR02 No. 1162 XX, power kW/rpm=213/2200 according to the Test Type: ECE R49 A30 Regulation, showed for fuel composition 7 in comparison to 100% Mk1 diesel fuel (SS 15 54 35) a reduction in the amounts of: CO (g/kW) 0 %, $HC+NO_x$ (g/kW) 0 %, particles (g/kW) 0 %.

The power (PkW) of the engine operated on fuel composition 7 decreased 0 % and fuel consumption (l/kW) increased 0 % in comparison with the results obtained on the same engine working on 100% Mk1 diesel fuel (SS 15 54 35).

Composition 8 demonstrates the possibility of using for the operation of a diesel engine a fuel composition consisting of a hydrocarbon liquid and organic compounds containing bound oxygen which is expedient for use under reduced ambient temperatures.

The contents by volume of the components in the fuel composition are ethanol 10 %, acetaldehyde diethyl acetal 2.5 %, dibutyl ether 5 %, di-isoamyl ether 6.5 %, butyl butyrate 3.5 %, methyltetrahydrofuran 5 %, isoamyl acetate 2 %, amyl nitrate 0.5 %, hydrocarbon liquid (Mk1 diesel fuel SS 15 54 35) 65 %.

The fuel composition has the following characteristics:

- density at 20°C 0.811 g/cm^3
- temperature limits of evaporation of
  the liquid by boiling at atmospheric pressure
  - up to 100°C 15 %
  - up to 150°C 25 %
  - up to 200°C 41.5 %
  - up to 285°C 96.5 %
- heat of combustion 40.4 MJ/kg
- thermal stability:
  fuel composition 8 is a homogeneous liquid stable at atmospheric pressure over the range of temperatures from minus 40 °C (cloud temperature) to plus 78 °C (initial boiling temperature).

An analysis of the amount of pollutants in the exhaust emissions of the standard diesel engine of the VW GOLF CL DIESEL automobile, engine family: D1-W03-92 when testing fuel composition 8 according to the Test Type – Modified European Driving Cycle (NEDC UDC + EUDC) ECE OICA (91/441/EEC) showed in comparison to the

results obtained for 100% Mk1 diesel fuel (SS 15 54 35) the reduction in the amounts of: CO (g/kW) 16.9 %, HC+NO_x (g/kW) 8.8 %, particles (g/kW) 20.5 %.

The use of the above mentioned fuel composition 8 for operation of the standard diesel truck engine, engine type VOLVO TD61GS No. 0580026, with power and torque settings: kW/Nm/rpm=140/520/1900, showed for measurements over the range 1000 - 2600 rpm a decrease in the values of power and torque of less than 3.5 % in comparison to the figures obtained for the same engine working on 100% Mk1 diesel fuel (SS 15 54 35).

Composition 9 demonstrates the possibility of using for the operation of a diesel engine a fuel composition for a diesel engine consisting of a hydrocarbon liquid and organic compounds containing bound oxygen for which the presence of 1 % of water does not worsen its characteristics and does not violate the stability of the system.

The contents by volume of the components in the fuel composition are water 1 %, ethanol 9 %, di-ethoxypropane 1 %, 1-butanol 4 %, methyl butyrate 4 %, 2-ethylhexanol 20 %, methyltetrahydropyran 5 %, dihexyl ether 5 %, isopropyl nitrate 1%, hydrocarbon liquid (Mk1 diesel fuel SS 15 54 35) 50 %.

The fuel composition has the following characteristics:

- density at 20°C 0.822 g/cm^3
- temperature limits of evaporation of
  the liquid by boiling at atmospheric pressure
  - up to 100°C 10 %
  - up to 150°C 25 %
  - up to 200°C 50 %
  - up to 285°C 97.5 %
- heat of combustion 39.4 MJ/kg

- thermal stability:

fuel composition 9 is a homogeneous liquid stable at atmospheric pressure over the range of temperatures from minus 36 °C (cloud temperature) to plus 78 °C (initial boiling temperature).

An analysis of the amount of pollutants in the exhaust emission of the standard diesel engine of the car VW Passat TDI 1.9 model 1997, engine family 2D1-WDE-95, power kW/rpm=81/4150 according to the Test Type – Modified European Driving Cycle (NEDC UDC + EUDC) ECE OICA (91/441/EEC) for fuel composition 9, showed in comparison to 100% Mk1 diesel fuel (SS 15 54 35) reduction in the amount of: CO (g/km) 22.4 %, HC+NO_x (g/km) 0 % and particles (g/km) 6.9 %.

An analysis of the amount of pollutants in the exhaust emission of the standard diesel truck engine, engine type: VOLVO D7C 290 EUR02 No. 1162 XX, power kW/rpm=213/2200 according to the Test Type: ECE R49 A30 Regulation showed for fuel composition 9 the following results in comparison to 100% Mk1 diesel fuel (SS 15 54 35) reduction in the amounts of: CO (g/kW) 6 %, HC+NO_x (g/kW) 0 %, particles (g/kW) 11 %.

The power (PkW) of this engine operated on the above mentioned fuel composition 9 decreased 3 % and fuel consumption (l/kW) increased 2 % in comparison to the results obtained for the same engine working on 100% Mk1 diesel fuel (SS 15 54 35).

Composition 10 demonstrates the fuel composition for a diesel engine consisting only of organic compounds containing bound oxygen all of which may be produced from renewable raw material of plant origin.

The contents by volume of the components in the fuel composition are ethanol 1 %, 1-butanol 4 %, 2-ethylhexaldehyde 10 %, acetaldehyde dibutyl acetal 6 %, di-2-ethylhexyl

ether 18 %, di-octyl ether 20 %, di-n-amyl ether 4 %, dibutyl ether 7 %, ethyl oleate 16 %, rape seed oil methyl ether 13.5 %, di-tert-butyl peroxide 0.5 %.

The fuel composition has the following characteristics:

- density at 20°C 0.830 g/cm^3
- temperature limits of evaporation of the liquid by boiling at atmospheric pressure
  - up to 100°C 1 %
  - up to 150°C 12.5 %
  - up to 200°C 50 %
  - up to 285°C 95.5 %
- heat of combustion 40.6 MJ/kg
- self-ignition temperature 150 °C
- thermal stability: fuel composition 10 is a homogeneous liquid stable at atmospheric pressure over the range of temperatures from minus 20 °C (cloud temperature) to plus 78 °C (initial boiling temperature).

An analysis of the amount of pollutants in the exhaust emission of the standard diesel engine of the VW Passat TDI 1.9 model 1997 automobile, engine family 2D1-WDE-95, power kW/rpm=81/4150 according to the Test Type – Modified European Driving Cycle (NEDC UDC + EUDC) ECE OICA (91/441/EEC) for fuel composition 10 showed in comparison with 100% Mk1 diesel fuel (SS 15 54 35) a reduction in the amount of: CO (g/km) 5.5 %, HC+NOx (g/km) 8.5 % and particles (g/km) 17.2 %.

An analysis of the amount of pollutants in the exhaust emission of the standard diesel truck engine, engine type: VOLVO D7C 290 EUR02 No. 1162 XX, power kW/rpm=213/2200 when executing Test Type: ECE R49 A30 Regulation, showed for

fuel composition 10 the following results in comparison with 100% Mk1 diesel fuel (SS 15 54 35) a reduction in the amounts of: CO (g/kW) 0 %, $HC+NO_x$ (g/kW) 0 %, particles (g/kW) 0 %.

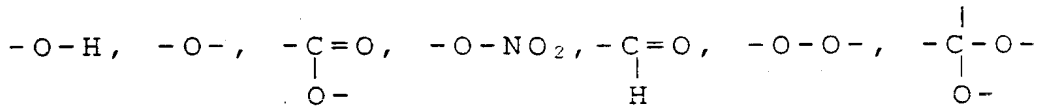
The power (PkW) of this engine operated on the above mentioned fuel composition 10 decreased 0 % and fuel consumption l/kW increased 0 % in comparison to the results obtained on the same engine working on 100% Mk1 diesel fuel (SS 15 54 35).

Each of the compositions 1-10 is prepared according to the invention by means of pouring together of the required amount of components in the same tank at the same temperature in a pre-determined order as follows, starting with the component having at that temperature the least density and finishing with the component having the highest density, and holding the mixture obtained for not less than one hour.

THE CLAIMS DEFINING THE INVENTION

The claims defining the invention are the following:

1. A motor fuel for diesel engines comprising hydrocarbon compounds and/or organic compounds containing bound oxygen, which constitutes a stable homogeneous liquid at atmospheric pressure and normal ambient temperature and achieves a reduction of harmful pollutants in the exhaust emissions of diesel engines by adding organic compounds containing oxygen bound in the following functional groups



to the fuel composition.

2. A motor fuel as in claim 1 wherein at least four types of different organic compounds containing bound oxygen chosen from the following classes: alcohols, aldehydes, ethers, organic esters, inorganic esters, acetals, organic oxides and peroxides; are added into the fuel composition, furthermore, molecules of these compounds should preferably be of linear or sparsely branched structure.

3. A motor fuel as in claim 2 wherein the total concentration of organic compounds containing bound oxygen in the fuel composition varies within the limits of minimum 5 % and of maximum 100 % of the total volume of the fuel composition, and the concentration of the hydrocarbon compounds varies, correspondingly, within limits of maximum 95 % and of minimum 0 % of the total volume of the fuel composition.

4. A motor fuel as in claim 3 wherein the fuel composition has the following properties:

   - density at 20°C, not less than 0.775 g/cm^3;
   - stable at atmospheric pressure over the range of temperatures between minus 0 °C (cloud temperature) and plus 50 °C (initial boiling point);
   - limits of evaporation of the liquid by boiling at atmospheric pressure:

- not more than 25 % of the total volume of the fuel composition distills at temperatures not higher than 100°C;
- not more than 35 % of the total volume of the fuel composition distills at temperatures not higher than 150°C;
- not more than 50 % of the total volume of the fuel composition distills at temperatures not higher than 200°C;
- not less than 98 % of the total volume of the fuel composition distills at temperatures not higher than 370°C;

- heat of combustion on oxidation by oxygen, not less than 39 MJ/kg;
- self-ignition temperature not lower than 150 °C and not higher than 300°C.

5. A motor fuel as in claim 4 wherein the preparation of the fuel composition is carried out by successive pouring into the same tank of the required amount of components at the same temperature in a pre-determined order as follows, starting with component having the least density at that temperature and finishing with the component having the highest density at that temperature, and subsequent keeping of the prepared composition for not less than one hour.

6. A motor fuel as in claim 5 wherein, for preparation of the fuel composition, not only a diesel fraction, but also lighter fractions of hydrocarbons are used.

7. A motor fuel as in claim 5 wherein, for preparation of the fuel composition, methanol and/or ethanol as well as products of their processing are used as the organic compounds containing bound oxygen .

8. A motor fuel as in claim 5 wherein technical products not thoroughly purified of admixtures are used for the preparation of the fuel composition.

9. A motor fuel as in claim 5 wherein fuel compositions stable at atmospheric pressure over the range of temperatures between minus 35 °C (cloud temperature) and plus 180 °C (initial boiling temperature) are prepared for operation under conditions of reduced or elevated ambient temperatures.

10. A motor fuel as in claim 5 wherein the fuel composition contains 1 % water in the total volume of the motor fuel.

11. A motor fuel as in claim 5 wherein the fuel composition consists of organic compounds containing bound oxygen which are obtained from renewable plant resources.

INTERNATIONAL SEARCH REPORT

International application No.
PCT/SE 99/01546

A. CLASSIFICATION OF SUBJECT MATTER

IPC7: C10L 1/02, C10L 1/18
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC7: C10L

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

SE,DK,FI,NO classes as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 9502654 A1 (VICTORIAN CHEMICAL INTERNATIONAL PTY LTD), 26 January 1995 (26.01.95), see page 6, comp. 9	1-11
X	GB 2090612 A (INSTITUT FRANCAIS DU PETROLE), 14 July 1982 (14.07.82), see page 1, line 30 - page 2, line 5	1-11
X	US 4364743 A (WILLIAM E. ERNER), 21 December 1982 (21.12.82), see example 2	1-11
X	EP 0014992 A1 (BASF AKTIENGESELLSCHAFT), 3 Sept 1980 (03.09.80)	1-11

[X] Further documents are listed in the continuation of Box C. [X] See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" erlier document but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance: the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance: the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
25 May 2000	05 -06- 2000
Name and mailing address of the ISA/ Swedish Patent Office Box 5055, S-102 42 STOCKHOLM Facsimile No. +46 8 666 02 86	Authorized officer Anna Sjölund/EÖ Telephone No. +46 8 782 25 00

Form PCT/ISA/210 (second sheet) (July 1992)

INTERNATIONAL SEARCH REPORT

International application No.
PCT/SE 99/01546

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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	--	

Form PCT/ISA/210 (continuation of second sheet) (July 1992)

INTERNATIONAL SEARCH REPORT

International application No.
PCT/SE 99/01546

Box I Observations where certain claims were found unsearchable (Continuation of item 1 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☒ Claims Nos.: 1-2
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

see next sheet

3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).:

Box II Observations where unity of invention is lacking (Continuation of item 2 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.

2. ☐ As all searchable claims could be searched without effort justifying an additional fee, this Authority did not invite payment of any additional fee.

3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

☐ The additional search fees were accompanied by the applicant's protest.

☐ No protest accompanied the payment of additional search fees.

INTERNATIONAL SEARCH REPORT

International application No.
PCT/SE 99/01546

Present claims 1-2 relate to an extremely large number of possible fuel compositions. The novelty search revealed a vast amount of novelty-destroying documents. Therefore, the search and the search report, have been mainly limited to such examples and compositions mentioned in the description. Only a selection of the relevant documents have been cited in the search report.

Also, present claims 1-11 relate to fuel defined by reference to several desirable characteristics or properties, e.g. (claim 1 "achieves a reduction of harmful pollutants in the exhaust emissions." .The claims cover all compositions having this characteristic or property, whereas the application provides support within the meaning of Article 6 PCT and/or disclosure within the meaning of Article 5 PCT for only a very limited number of such compositions. In the present case, the claims so lack support, and the application so lacks disclosure, that a meaningful search over the whole of the claimed scope is impossible. Independent of the above reasoning, the claims also lacks clarity (Article 6 PCT). An attempt is made to define the fuel compositions by reference to a result to be achieved. Again, this lack of clarity in the present case is such as to render a meaningful search over the whole of the claimed scope impossible. Consequently, the search has been carried out for those parts of the claims which appear to be clear, supported and disclosed, namely those parts relating to the examples and compositions mentioned in the description.

INTERNATIONAL SEARCH REPORT

Information on patent family members

02/12/99

International application No.
PCT/SE 99/01546

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.
PCT/SE 99/01546

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